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TEST TECHNOLOGY STRATEGY

V Leonard

April 1981

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Prepared for
Chief of Naval Material

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

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ADMINISTRATIVE INFORMATION

This document was prepared to set forth the goals, objectives, and approach of an overall strategy to meet the Navy's future test technology needs. The strategy summarizes the Test Technology Strategy Team programs and proposals that have developed into the comprehensive and coordinated U. S. Navy Test Technology RDT&E Plan. Work was performed by the Naval Ocean Systems Center under O&MN funding. This document is intended for use by DoD and industry technical personnel performing research and development.

The author thanks the Navy Test Technology Strategy Team for their review and implementation of this documented strategy.

Released by
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Under authority of
P. C. Fletcher, Head
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This report summarizes the US Navy Test Technology RDT&E Plan and defines critical needs for research in this area.

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A. INTRODUCTION

Weapon systems in the Fleet and in development are ~~utilizing~~ using complex and sophisticated new technologies to extend Fleet capabilities and effectiveness. Designers are developing systems that respond more rapidly and with greater lethality and systems that are tightly integrated in the command/control hierarchy. Complex and sophisticated weapon systems require high maintenance skill levels. Naval personnel studies reveal fewer technician resources are available. There is a growing disparity between maintenance level requirements and maintenance personnel resources. Manpower, skills, and time to manually test and diagnose complex weapons are not available.

The Navy's research community is aware of the problems ~~that are being~~ created for the Fleet by systems complexity, new technology, and manpower shortages. A Test Technology Strategy Team ~~has~~ planned the essential tasks for ~~the~~ development of the test technologies required to address a major portion of these problems. The strategy team now coordinates and maintains these tasks in the "Navy Test Technology RDT&E Plan." Implementation of this plan will radically reduce Fleet maintenance problems and avoid future problems with untestable new technologies.

B. SCOPE

The strategy presented ~~herein~~ describes a test technology base which has application across the spectrum of weapon systems. Test technology must be developed for machinery and electronics to perform automatic tests from the systems level down to built-in test (BIT) within integrated circuits and mechanical devices. Software must be developed to enhance internal and external testing, while other emphasis is essential for design aids to make future systems more easily testable and maintainable.

The area of Test Technology has been divided into seven major thrusts to provide the focus for technical specialists.

Thrusts

1. Automatic Test Equipment (ATE) Software
2. Automatic Test Program Generation
3. Design for Testability
4. Machinery Testing
5. New Technology
6. Advanced Automatic Testing Concepts
7. Calibration

Definition and Boundaries

Automatic Test Equipment (ATE) includes the hardware and software that perform tests on prime systems by other than manual test methods.

BIT is a form of ATE that is an integral part of a prime system and is synonymous with on-line automatic test.

Testability is a design characteristic which allows the status (operable, inoperable or degraded) of a unit (system, subsystem, module or component) to be confidently determined in a timely fashion.

Test Technology refers to a technology base required to enhance the maintainability and availability of naval weapon systems.

Test Technology application opportunities are as extensive as testing itself. All systems and devices that have test requirements can benefit from the development of a test technology base.

Approach

The diverse nature of test technology and the broad base of application opportunities have resulted in the development of a Navy team known as the Test Technology Strategy Team. Fleet Support Activities, as part of this Team, identify Fleet needs and provide user perspectives. Team members from the many Navy Laboratories and SYSCOM Activities are charged with the responsibility for development of test technologies peculiar to their product areas. Close liaison is maintained to avoid duplication, provide for information exchange, and maintain a Navy-wide corporate memory.

Relationship to Other Strategies

This strategy defines a technology base that is vital to all operational and mission support strategies. The ultrasophisticated new weapons systems being developed by the mission strategies will not be fully effective without the availability of an applicable test technology to make these systems readily maintainable. Members of the Test Technology Strategy Team affiliated with a specific Navy activity have volunteered and are assigned to serve on the other Navy Technical Strategy Teams. This involvement in other strategies will increase the visibility of test technology and provide feedback for future research.

C. OBJECTIVES

The major objective of the Test Technology Strategy is to improve system operational availability. Maintaining high system availability is a function of how well the user can assess the operating condition of his equipment, how quickly he can detect and locate the degraded or failed components, and how efficiently he can repair or replace the malfunction. On-line automatic test, built into the weapon system, can inform operations and maintenance personnel of current status and of actions needed to return equipment to operational status.

Both the Navy and Marine Corps are faced with the increasingly critical problems of:

- Low availability of systems
- Reductions in manpower
- Increasing sophistication of new systems
- Training
- Inability to respond to timely threats
- Increasing life cycle costs
- Inadequate or non-existent operational monitoring systems

These critical problem areas can be drawn together into four broad objectives, which have been used to provide guidance to the evaluation of the test technology base:

- Resolve Current Operational Performance Deficiencies

  There are a number of high-priority operational problems for which test technology can provide important capabilities. The technology base must evolve in a manner responsive to these priority deficiencies, such as availability.

- System Life Cycle Cost Reduction (acquisition, operation, and maintenance, and reliability costs)

  A critical problem area is the escalating impact of test, maintenance, and logistics on life cycle cost. Current estimates are that the O&MN costs of maintenance during the service life of electronic systems average at least six times their acquisition costs. O&MN costs are also increasing due to the proliferation of electronic systems, subsystems, modules, and circuits which perform similar functions under similar operational environments, but which require independent training, maintenance, and logistic support.

- Avoid Future Operational Performance Deficiencies

  The evolution of more sophisticated threats over a 5- to 20-year period and of new U.S. Navy platforms to meet these threats will stress performance and form factor constraints on future naval systems. Technical resources should be invested to identify deficiencies in the supportability of these complex new systems now in development and establish a technology base for overcoming them.

- Stay Abreast with New Technologies

  The final broad objective is to provide a test technology base which supports revolutionary breakthroughs in combat system capabilities (e.g., tactical use of satellite surveillance sensors, RPV sensors).

D. THREAT

All warfare areas are driving the advancement of technology and the development of systems of ever-increasing complexity to maintain our present advantage over increasingly sophisticated enemy weapons. The primary threat to the Navy's ability to perform its missions, of concern to this strategy, is inadequate operational readiness indicators, which are perceived to have these major elements:

Enemy Capabilities: Future naval encounters will involve rapid long-range strike capabilities from enemy vessels with a destructive power far exceeding the capabilities of larger vessels in previous wars. Total ship's readiness is essential to initiate the offensive or to survive the enemy's attack and mount a counterattack. In the event of reduced readiness, the ship's command or aircraft pilot must know immediately what resources can be brought to bear to maximize the possibilities of success and minimize potential losses. Current and continually updated readiness assessment data with reconfiguration possibilities are required to enable accurate and rapid decisions by the command. The development of automated systems capable of continually monitoring and evaluating systems readiness will enhance the Navy's ability to meet these threats.

Environment: In order to maintain parity, the sophisticated systems being introduced in the Fleet utilize new technologies and are increasingly more complex. Frequently weapon systems are deployed before the support capability is developed, thus linking the ship's operational capability to factory support, which would not be adequate in time of war. The

complexity of diagnosing failed operational systems has severely overburdened the maintenance capabilities of the Fleet, thus increasing down time for maintenance and reducing operational availability. The maintenance workload can be reduced through the use of effective automated test, monitoring, and diagnostic techniques.

Economics: The increasing cost of maintaining existing Navy systems is consuming an ever greater portion of the Navy's total budget. It is essential that program managers direct considerable attention towards the specification of contractor requirements aimed at reducing the support costs of new systems. Testable and diagnosable prime system designs have been determined to be a major driver in reducing maintenance costs. The development of the technologies to implement testable designs must be actively pursued!

E. APPLICATION OPPORTUNITIES

Test technologies have both general and specific applications. The sensors to be developed for determining the operational status of high-speed turbines are very specific, while a voltage sensor has very broad application.

Guided Weapons

Guided weapons include missiles, smart bombs, torpedoes, mines, and remotely piloted vehicles. These weapons have a lot in common and are unique with respect to other groups of Navy systems. Maintenance Concepts such as the "wooden round" mean these weapons will not be externally tested before launching. The last comprehensive test of the weapon may have been performed many months ago at a shore station. This maintenance concept creates a significant opportunity, if not a requirement, for the application of test technology. BIT can and must be applied to these weapons to provide an essential minimal level of assurance that critical functions are operational just prior to launch. Fault-tolerant designs, applied when cost effective, can multiply the reliability of these weapons considerably. Design for testability will enable more comprehensive and lower cost tests of these weapons prior to deployment to an operational-level site.

Surface Ship Electronics

In order to meet the threats defined in Section D, the Commander of each ship will need to know almost instantaneously the operational status of all his systems. A test technology effort called Ships Automatic Test Equipment Program is working on this problem in 6.3. This creates a perfect opportunity in 6.2 to develop the technologies necessary to advance the operational capabilities of an ongoing 6.3 effort.

Machinery

Test technology has another excellent application opportunity in machinery testing. The problems of discerning the operational status of machinery prior to cataclysmic failure, which causes damage to other equipment, have been fully recognized. The Navy has proposed a 6.3 program to develop a "Shipboard Machinery Performance Monitoring System." The development of such a monitoring system will require considerable 6.2 support.

Submarine Electronics

Submarine systems give rise to the need to improve operational readiness, reduce maintenance, and eliminate external test equipment. The application of design for testability, employment of BIT, and fault-tolerant technologies would help meet these needs.

Avionics

Avionics systems are forced by increasing enemy capabilities to employ new technologies in increasingly more complex new systems. These new systems have exceeded the capabilities of Fleet maintenance to provide support. New test technologies are required in many cases because no test capability exists. An opportunity exists to reverse the trend towards unaffordable maintenance costs and low readiness figures through application of BIT and Design for Testability technologies.

Automatic Test Equipment (ATE)

Lack of ATE compatibility considerations in prime system design is driving up the cost, complexity, and proliferation of ATE. Advanced ATE concepts, improved ATE software, automated-test-generation techniques, and BIT for ATE must be developed to support the Navy's heavy reliance on ATE.

Calibration

The Navy has experienced a considerable increase in the complexity of devices requiring calibration, but there has not been a parallel effort to advance calibration capabilities. There are several areas of calibration research identified as essential to recover from the Navy's current shortfall of calibration technologies.

F. SPECIFIC BASE THRUSTS

The Test Technology Base Thrusts are identified in Table 1 along with the Major Thrusts they are intended to implement. A brief description and level of effort of each thrust is shown in Table 2. Detailed task descriptions are maintained in the "U. S. Navy Test Technology RDT&E Plan."

TABLE 1.

TEST TECHNOLOGY BASE THRUSTS

ATE Software

- o Develop Common Facilitating Software
- o ATE Self-Test Software
- o Micro Diagnostics for ATE Self-Test
- o Micro Diagnostics for ATE

Automatic Test Program Generation (ATPG)

- o Develop Analog ATPG System
- o Develop ATPG using CAD Tools

Design for Testability

- o Testability Figures of Merit
- o Testability Standardization
- o Statistical Fault Monitoring Demonstration
- o Air Launched Missile Testability
- o Fault-Tolerant Design
- o Test Technology for Underwater Weapons Systems

Machinery Testing

- o Machinery Diagnostics Development
- o Machinery Failure Prognosis
- o Machinery Failure Prediction Modeling
- o Sensor/Transducer Requirements Identification and Development

New Technologies

- o Technology Assessment
- o Digital Fiber Optic Status Monitors
- o EO-GSE Advanced Technology
- o EO-GSE Laser Test Technology
- o Battery Failure Predict & Detect
- o EO-GSE Multi-Purpose Collimator
- o EO-GSE Automatic Signal Analysis and Evaluation

Advanced Automatic Test Concepts

- o Test/Maint./Calibration Technology
- o ATE Standard Interface
- o Fault Location Algorithm Investigation
- o Microwave Tube Protection
- o Advanced Test Technology
- o Shipboard Fail. Detect. & Perf. Monitor
- o Near Field Antenna Measurement
- o Relate Maintenance Concepts to Automatic Test Requirements
- o Fault-Tolerant Building Blocks
- o Microwave ATE
- o Test Technology for Analog Systems
- o Microprocessor Test and Repair

Calibration

- o Development of Systems Calibration Techniques
- o Standards for Millimeter Wave Systems
- o Picosecond Pulse Measurement System
- o System Calibration ATE
- o Standards for Support of Digital Systems
- o Storage Effects on Electronic Equipment
- o Development of ATE Design for Calibration/Guidelines
- o Beam Uniformity Measurements for Laser Systems
- o Calibration Standards for Gas/Liquid Analyzers
- o Contactless Measurement of Liquid Flow
- o Transfer Standards to Audit Manometer Standards
- o Electro-Optical Technology
- o Nd:YAG Laser Calibration Systems with Emphasis on Safety
- o Josephson-Effect Voltage Standard

TABLE 2

THRUST DESCRIPTIONS

Thrust	Description
	ATE SOFTWARE
o Develop Common Facilitating Software	The purposes of this task are: (1) The continued continued development of statistical fault theoretical concepts for sampled monitoring, (2) The specification and development of monitoring demonstration software tools for analysis and simulation modeling in support of the theoretical concept development, and (3) The experimental validation and "proof of concept" of both theoretical results and simulation models utilizing a hardware textbook.
o ATE Self-Test	Determine what software techniques can be used to evaluate the operability of components common to ATE. Develop techniques and standards to implement monitoring of ATE and components. Implement these techniques in a complex ATE and evaluate the results.
o Micro-diagnostics for ATE Self-Test	The objective of this project is to establish concepts and devise techniques for implementing ATE self-tests with microdiagnostics in order to reduce hardware and software costs, maintenance costs, and training costs, while increasing station availability.
o Micro-diagnostics for ATE	To improve the maintenance on ATE within the Navy by supplying internal micro-coded programs for diagnostics within ATE systems.
	AUTOMATIC TEST PROGRAM GENERATION
o Develop Analog ATPG System	Continue development of Analog ATPG techniques and software by combining three unique algorithms that automatically analyze analog circuits.

Thrust	Description
	AUTOMATIC TEST PROGRAM GENERATION
o Develop ATPG Using CAD Tools	The purpose of this effort is to examine the feasibility of using computer-aided design (CAD) tools to enhance the automatic test generation capability, especially in the area of analog circuit diagnostics. This effort will combine the models and tools presently being developed to support automatic test generation for analog circuits with present CAD software tools to determine their applicability to computer-aided test. A CAD specification will be developed to perform testability analysis and compute a testability figure of merit for inclusion in the normal CAD results.
	DESIGN FOR TESTABILITY
o Testability Figures of Merit	Define testability parameters that lead to establishing a meaningful figure of merit for design testability. Develop algorithms for measuring inherent testability.
o Testability Standardization	Provide uniform guidance in the managerial aspects of testability by developing and proofing testability parameters to be included in testability specifications.
o Statistical Fault Monitoring Demonstration	Off-line software is required to facilitate preparation of test program software. This involves Translators, Compilers, TPS Generators, Media Converters, Syntax Comparators and other support processors. Common Facilitating Software would reduce the proliferation of such software and increase TPS portability.
o Air-Launched Missile Testability	Develop air-launched missile BIT technology and requirements for testable design.
o Fault-Tolerant Design	Investigate concurrent fault-monitoring techniques developed for other on-line fault-detection approaches. Integrate fault detection into fault tolerance. Develop fault-tolerant computer requirements and specifications. Expand fault tolerance into all critical types of devices.

Thrust	Description
	DESIGN FOR TESTABILITY
o Test Technology for Underwater Weapons Systems	Develop individual testability specification criteria for the assorted types of underwater systems.
	MACHINERY TESTING
o Machinery Diagnostics Development	Conduct an in-depth failure analysis on selected machines to determine those primary and/or secondary effect parameters that reveal the actual condition of the machine. Develop diagnostic and prognostic techniques.
o Machinery Failure Prognosis	Develop viable techniques and methods for machinery failure prognosis. Investigate feasibility of using mathematical failure prediction models.
o Machinery Failure Prediction Modeling	Conduct a state-of-the-art assessment and provide recommendation for research and exploratory development in modeling and simulation of incipient failures of shipboard machinery. Provide technical examples and cases of application for promising failure prediction models which may advance through exploratory development.
o Sensor/Transducer Requirement Identification and Development	Develop a catalog of existing machinery sensors applicable to automatic testing, and document their technical descriptions and application criteria. A study will be performed to determine the need for the development of additional sensors and transducers. The new sensors that will be required will be developed. They will also be tested for reliability and qualified for service use worthiness.
	NEW TECHNOLOGIES
o Technology Assessment	Develop a Navy-wide technology assessment capability. Review all 6.1, 6.2 & 6.3 programs in process at Navy Laboratories. Compile brief descriptions of programs with potential and prepare a Navy Test Technology Impact Report. Provide the Army and Air Force assessment guidelines and develop a Joint Services Test Technology Impact Report. Investigate methods and benefits of IR&D technology assessment.

Thrust	Description
	NEW TECHNOLOGIES
o Digital Fiber Optic Status Monitors	Develop electrically passive optical energy sensing and transmission capabilities through fiber optic probes. Applications include sensing elements for flight and engine control by measuring parameters such as displacement, temperature, pressure, fuel level, flow rate, speed, and strain.
o EO GSE Adv. Technology	Develop requirements for next generation of electro-optical ATE with recommendations for common tri-service test hardware and methods. Develop electro-optical testability guidelines and standard test interface requirements.
o Electro-Optics GSE Laser Test Technology	Develop an optimum mix of built-in tests and external tests to meet the requirements for laser tests and alignments, including high-power sections of such equipment.
o Battery Failure Predict. & Detect.	Analyze silver-zinc battery failure modes and related chemical processes. Develop probes to detect chemical change and predict remaining life and or reliability. Evaluate other new-technology batteries for test technology requirements.
o Electro-Optics GSE Multi-Purpose Collimator	Design and develop a multi-purpose electro-optic collimator with wide-bandpass that is compact, affordable, producible, and suitable for Fleet support of a wide class of E-O sensors and platforms.
o Electro-Optics GSE Automatic Signal Analysis and Evaluation	Develop methods and techniques for the automatic analysis and evaluation of electronic signals, voltages, and waveforms so as to minimize the need for human intervention and interpretation of these signals.

Thrust	Description
	ADVANCED AUTOMATIC TESTING CONCEPTS
o Test/Maintenance/ Calibration Techniques	The objective of this program is to develop concepts and techniques for quantitatively measuring the performance capability of communication and Electronic Warfare systems in a cost-effective manner. Included are concepts for both dockside and sea-based testing. The thrust of this program is the development of a calibrated system test for use at dockside to precisely determine the capability of a system to perform to its design specification. These measurements act as a baseline from which to measure system operational readiness.
o ATE Standard Interface	Develop an approach to automatic test system design that emphasizes low acquisition cost yet provides versatility as required in the repair environment.
o Fault Location Algorithm Investigation	The technical objective is to achieve an inexpensive, simple procedure to detect,diagnose, and predict faults in analog circuitry used in naval electronic systems. The objective of this particular effort is to develop and test a method based on a learning approach to the design of a fault diagnosis scheme which is applicable to a wide range of analog circuits and systems when realistic parameter variation in non-faulty components and noise are taken into consideration.
o Microwave Tube Protection	Develop an understanding of crossed-field amplifier tube interaction processes of tapered anode-cathode spacing and pitch with respect to related failure modes. Develop monitoring and protection devices.
o Advanced Testing Technology	Devise techniques for measurement, processing, and display of system readiness data useful to maintenance personnel on each shipboard prime system.
o Shipboard Auto. Failure Detection & Performance Monitoring	Analyze surface ship test requirements that are sensitive to ship's operational objectives. Define parameters to be monitored and monitoring equipment. Develop measures of effectiveness for fault isolation andmonitoring configurations.
o Near Field Meas. Technology	Develop advanced algorithms to provide boresight and radiation pattern testing for installed airborne antennas.
o Relate Maintenance Concepts to Automatic Test Requirements	Develop techniques and guidelines for relating maintenance philosophies and concepts to automatic testing requirements.

Thrust	Description
	ADVANCED AUTOMATIC TESTING CONCEPTS
o Fault-Tolerant Building Blocks	Define and characterize the VLSI building block circuits required to combine microprocessors and memories into a wide variety of fault-tolerant computing systems. Develop self-checking computer modules.
o Microwave ATE	The objective is to maintain efficient technological support for future RF and microwave avionics through the development of concepts directed towards systems of the 1980-2000 time period.
o Test Techniques for Analog Systems	Investigate implementation of selected traditional analog functions by means of digital circuitry. Design an analog device functional simulator for new design performance investigations. Develop design guidelines for building self-contained test (SCT) into analog devices. Develop an analog hardware classification system for design use, allowing easy transfer of software elements for test of analog device functions, interfaces, and circuits by categories.
o Microprocessor (MP) (Electronic Module/ PCB) Test and Repair	Determine the impact of "remove and replace" versus "test and repair" for microprocessor-based equipments. Assess the feasibility of testing and/or repairing failed EM/PCBs. If warranted, based on cost or availability, identify MP self-test techniques as part of equipment BIT to detect/diagnose EM/PCB faults and determine off-line ATE test techniques needed for detection/diagnosis of MP EM/PCBs.
	CALIBRATION
o Development of System Calibration Technology	Develop techniques and technologies to implement a system calibration capability for test systems, such as ORMS, imbedded in larger systems, such as ships. Assess and adapt concepts developed for other applications to develop such techniques as computer-based calibration.
o Picosecond Pulse Measurement System	Develop the capability to calibrate subnanosecond pulse test equipment to a maximum uncertainty of $\pm 1\%$.
o System Calibration of ATE	Develop means to maintain ATE within specified calibration standards while reducing related down time.

Thrust	Description
	CALIBRATION
o Standards for Digital Systems	P~rform investigations to characterize the key dynamic performance parameters for AD/DA circuitry. Develop and evaluate calibration standards and methods for AD/DA devices.
o Storage Effect on Electronic Equipment	Devise method for modeling and analysis of storage effects data.
o Develop Guidelines for ATE Design	Develop ATE design guidelines on these characteristics to promote calibratibility: Calibration system interfaces, access to system modules, system self-calibration software, performance requirements for calibration standards, automatic calibration.
o Beam Uniformity Measurements for Laser Systems	Develop a quantitative definition for laser beam uniformity. Study far field intensity distribution on a per-pulse basis to eliminate hot spots in laser resonators. Develop simulation techniques for beam profile at 1.06 microns.
o Calibration Standard for Gas/Liquid Analyzers	Develop low-cost stable standards for calibrating gas/liquid analyzer and detectors.
o Contactless Measurement of Liquid Flow	Investigate techniques and develop concepts for contactless measurement of liquid flow.
o Transfer Standards to Audit Manometer Standards	Develop rugged transfer standards to audit pressure calibration standards.
o Electro-Optical Technology	Develop Electro-Optical (EO) calibration technologies and techniques to support emerging test and alignment equipment. Provide research to support the ongoing advanced development EO calibration task.
o Nd:YAG Laser Calibration System with Emphasis on Safety	Develop safe methods to calibrate new laser test equipment that will be capable of measuring eleven laser parameters.
o Standards for Millimeter Wave Systems	Develop standards in the 93- to 95-GHz range, such as a six-port automatic network analyzer and a calorimeter for power measurements.
o Josephson-Effect Voltage Standard	Develop cryogenic Josephson-effect voltage standards that are impervious to external environments. Develop high-temperature coefficient superconducting Josephson junctions.

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